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Air-separation apparatus, integrated air-separation and metal-production apparatus and method of starting one such air-separation apparatus

5 The present invention relates to an air separation unit, to an integrated air-separation/metal production installation and to a method of starting up such an air separation unit.

10 As described in the article "Optimized Steel Production with Oxygen for Blast Furnaces at ILVA, Taranto Works, Italy" by Capogrosso et al., Steel Times International, February-March 2003, it is known to feed an air separation unit at least partly with compressed air from the blower of a blast furnace. The oxygen produced by the unit is then mixed with the rest of the air coming from the blower, heated and sent to the blast furnace.

15 It is frequently necessary for a portion of the air coming from the blower and intended for the air separation unit to be boosted.

20 The article explains that the air may come from a compressed-air main fed by several blowers.

25 Suitable air separation units for feeding a blast furnace are described in US-A-5 244 489, US-A-6 089 040, US-A-6 119 482 and US-A-6 122 932.

30 To start up the blast furnace, it is firstly necessary to turn the blower on. The pressure of the air gradually increases up to a pressure that allows the booster compressor for compressing the air intended for the air separation to start.

35 It is obviously important to be able to start up this booster compressor rapidly so as to deliver oxygen to

the consumer as quickly as possible, so that the blast furnace can operate normally.

5 It is an object of the present invention to reduce the minimum air pressure at which the booster compressor can start to operate.

10 One subject of the invention is an air separation unit comprising a system of columns, means for feeding the unit at least partly with compressed air coming from at least one booster compressor, means for purifying and cooling the air, means for sending it to one column of the column system and means for withdrawing a gaseous product from one column of the column system, 15 characterized in that the booster compressor is driven by a variable-speed motor having at least two nominal rotation speeds.

20 The variation in the frequency of the supply and/or of the load means that the motor having a nominal speed of x revolutions will turn in fact at about this speed within a range of $\pm 5\%$ at most.

25 - The unit includes means for supplying the motor with a variable-frequency AC current;
- The unit includes a multi-speed motor;
- The motor is of the type having a single primary winding, in particular a Dahlander winding, or of the type having several primary windings.

30 Another subject of the invention is an integrated air-separation/metal-production installation comprising an air separation unit, a metal production unit, a main compressor that compresses air intended for the air separation unit and air intended for the metal production unit, the air separation unit being of the type defined above, means for sending air from the main compressor to the booster compressor and means for

sending the gaseous product coming from the air separation unit to the metal production unit.

Another subject of the invention is a method of
5 starting up an air-separation/metal-production installation comprising a system of columns, means for feeding a booster compressor with compressed air and means for sending air from the booster compressor to at least one column of the column system and means for
10 withdrawing a gaseous product from one column of the column system in order to send it to the metal production unit, characterized in that the booster compressor is driven by a variable-speed motor and in that, during a startup period of the metal production
15 unit, the speed of the motor is higher than the speed of the motor during steady operation of the unit.

According to other optional aspects:

- the motor turns at one of the two speeds, the
20 motor turning at a first speed during startup of the metal production unit and at a second speed during steady operation of the unit, the first speed being higher than the second speed;
- the motor is supplied with AC current at a
25 higher frequency during startup of the metal production unit than the frequency of the current during steady operation of the unit;
- the motor is supplied with a variable-frequency current; and
- 30 - the motor comprises several windings differently coupled depending on the operation of the unit.

Yet another subject of the invention is a method of the abovementioned type, in which an air separation unit
35 and a metal production unit are fed with air from a main compressor and the metal production unit is fed with a gaseous product from the air separation unit, in which method the main compressor that feeds the two units is started first and then the air separation unit

according to the abovementioned startup method is started.

5 The rotation speed of the motor may be adjusted by various means:

- it is possible to change the number of pairs of poles on machines having a single primary winding (with Dahlander-type winding coupling) or machines having several primary windings;

10 - it is possible to change the frequency of the stator supply voltage using electromechanical frequency converters or static converters; and

15 - it is possible to change the slip, by varying the status supply voltage using a slip rheostat to the rotor or using a recovery cascade.

All the pressures mentioned are absolute pressures.

20 The invention will be described in greater detail with reference to the drawings, which are diagrams showing the principle of an air separation unit according to the invention integrated with a blast furnace.

25 Figure 1 shows a metal treatment unit, in this example a blast furnace BF, and an air distillation unit comprising an exchange line EL, a double column DC and a mixing column MC, the blast furnace and the air distillation unit both being fed with air by a blower C that typically produces more than 100 000 Sm³/h of air
30 at a pressure of at least 6 bar, typically between 3 and 5.5 bar. The blower C may feed other units. The air intended for the blast furnace BF is heated and sent to the blast furnace after having been mixed with a stream of oxygen O coming from the air separation unit.

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The air distillation unit shown in Figure 1 is intended to produce low-purity oxygen in a first operation, for example with a purity of 80 to 97% and preferably 85 to 95% at a specified pressure P different from 7 bar, for

example at 2 to 6 bar, or else at a pressure above 7 bar by at least 2 bar and possibly up to 14 bar, preferably between 9 and 14 bar. The double distillation column DC itself comprises a medium-
5 pressure column MPC, a low-pressure column LPC and a main reboiler/condenser. The columns MPC and LPC typically operate at about 6 bar and about 1.2 bar, respectively.

10 As explained in detail in document US-A-4 022 030, a mixing column is a column that has the same structure as a distillation column but is used for mixing, in a manner close to reversibility, a relatively volatile gas introduced at the bottom of the column with a less volatile liquid introduced at the top of the column.

Such mixing generates refrigeration energy and therefore makes it possible to reduce the consumption of energy associated with the distillation. In the
20 present case, this mixing is also profitably used for direct production of impure oxygen at the pressure P , as will be explained below.

The air intended for the distillation is cooled by a
25 cooler CL and purified by a purification unit PU. Next, it is divided into two streams. The stream L is boosted in a booster compressor C2 up to a pressure of 6×10^5 Pa and then cooled in the exchange line EL and introduced into the bottom of the mixing column MC.

30 The other stream J is sent to the exchange line EL, partially cooled and divided into two. One portion is sent to the medium-pressure column MPC after being cooled right to the cold end of the exchange line and
35 the other portion is expanded to the low pressure in a turbine T and then injected into the low-pressure column LPC at an intermediate point.

The booster compressor C2 is driven by a variable-speed motor M with at least two nominal speeds. This motor may be of the Dahlander type with two or three speeds, as described in Memotech Electrotechnique de Bourgeois 5 et Cogniel, published by Educalivre, page 295. During a startup period of the metal production unit, the speed of the motor is higher than the speed of the motor during steady operation of the unit. Optionally, the booster compressor may also be driven by a turbine, 10 such as a steam turbine.

"Rich liquid" (oxygen-enriched air), withdrawn from the bottom of the column MPC, is, after being expanded in an expansion valve, introduced into the column LPC 15 close to the point of injection of the air. "Lean liquid" (impure nitrogen) withdrawn at an intermediate point from the column MPC, is, after being expanded in an expansion valve, introduced into the top of the column LPC. Nitrogen N constituting the waste gas of 20 the unit, and possibly pure gaseous nitrogen at the medium pressure produced at the top of the column MPC are warmed in the exchange line EL and discharged from the unit.

25 Liquid oxygen, the purity of which depends on the setting of the double column DC, is withdrawn from the bottom of the column LPC, brought by a pump W to a pressure P_1 slightly above the aforementioned pressure P , in order to take into account the pressure drops 30 ($P_1 - P$, for example less than 1×10^5 Pa), and introduced into the top of the column MC. P_1 is therefore advantageously between $4 - 6 \times 10^5$ Pa and 30×10^5 Pa, preferably between 8×10^5 Pa and 16×10^5 Pa. Withdrawn 35 from the mixing column MC are the following three fluid streams: at the base of the column, liquid close to the rich liquid and combined with the latter via a line provided with an expansion valve; at an intermediate point, a mixture essentially composed of oxygen and nitrogen, which is sent at an intermediate point of the

low-pressure column LPC via a line provided with an expansion valve; and at the top of the column, impure oxygen which, after being warmed in the heat exchange line, is discharged, at approximately the pressure P ,
5 from the unit via a line as production gas O.

Figure 1 also shows auxiliary heat exchangers for recovering the refrigeration available in the fluids circulating in the unit.

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In the example shown in Figure 2, all the air intended for distillation is compressed in a booster compressor C1 driven by a variable-speed motor M. The boosted air is then purified in a purification unit PU, cooled and
15 divided into two portions. One portion of the air is boosted to the pressure of the mixing column MC in a booster compressor c coupled to the blowing turbine T which is fed by one portion of the rest of the air.

20 The other components of the figure are identical to those of Figure 1.

In Figure 3, as in Figure 2, all the air intended for distillation is compressed in a booster compressor C1 driven by a variable-speed motor M. The boosted air is then purified in a purification unit PU and a portion L of the purified air is boosted to the pressure of the mixing column in a second booster compressor C2 also coupled to a motor M' , possibly a variable-speed motor.
25 This air is cooled in the exchange line EL and sent to the mixing column MC. The remainder J of the air coming from the purification unit is partially cooled and divided into two portions. One portion of the air is sent to a turbine T and then to the low-pressure column
30 LPC. The remainder of the air continues to be cooled in the exchange line EL and is sent in gaseous form to the medium-pressure column.
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The turbine T is driven by a low-pressure nitrogen compressor c.

It is also conceivable for the double column to be fed
5 by means of the blower, while the mixing column is fed
by means of a dedicated compressor, or otherwise.

The booster compressor may be used to feed the mixing
column and/or the mixing column.